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MYOSÓTIS: A DESIGN-BASED RESEARCH APPROACH FOR REAL-WORLD IMPACT

MYOSÓTIS: UMA ABORDAGEM DE INVESTIGAÇÃO BASEADA EM DESIGN PARA IMPACTO NO MUNDO REAL

MYOSÓTIS: UN ENFOQUE DE INVESTIGACIÓN BASADA EN EL DISEÑO PARA EL IMPACTO EN EL MUNDO REAL

Fátima Morais[1]
Sara Cruz[2] [0000-0002-9918-9290]
José Henrique Brito[3] [0000-0002-4544-4698]

[1]*Polytechnic Institute of Cávado and Ave, Barcelos, Portugal, a30065@alunos.ipca.pt*

[2]*2Ai – School of Technology, IPCA, Barcelos, Portugal & CIEd – Research Centre on Education, University of Minho, Braga, Portugal, scruz@ipca.pt*

[3]*2Ai – School of Technology, IPCA, Barcelos, Portugal & LASI – Associate Laboratory of Intelligent Systems, Guimarães, Portugal, jbrito@ipca.pt*

Abstract

The purpose of this paper is to describe the design, development, and educational enactment of the Myosótis Solution, an innovative mobile application and IoT-enabled prototype device aimed at preventing the accidental leaving of children or animals unattended in vehicles. The project was undertaken as part of a master's degree dissertation and employed a design-based (development) research methodology situated in an authentic school-based robotics setting. This paper reports on the iterative process of designing, testing, and refining the Myosótis App and its sensing–communication architecture, drawing on the principles of development research. The process began with the identification of the core problem and formulation of the primary research question. The design phase focused on integrating advanced sensors (e.g., CO_2, humidity, and presence detection via millimetre-wave (mmWave) radar) and wireless communication technologies (LoRa and GSM) to develop a responsive and user-friendly application capable of time-critical alerts. Throughout the research, key stakeholders, including educators, developers, technical experts, and end-users, were engaged in several iterations to evaluate and enhance the app's usability, functionality, and social impact. In parallel, the study examined how the project functioned as a STEAM learning design, supporting active learning and social responsibility among participating students through structured cycles of modelling, measurement, data interpretation, and algorithmic decision-making. The Myosótis App was found to be accessible, effective, and socially impactful, successfully addressing the critical issue of safety in vehicles while providing an empirically grounded example of how DBR can align technological innovation with educational aims. However, challenges such as development costs, technical limitations, and the need for further optimisation were identified. This study focused on a limited sample of participants and controlled environments. Further studies are required to assess scalability and adaptability in diverse contexts. The findings offer valuable insights for practitioners developing mobile applications aimed at addressing real-world safety concerns, particularly in educational and socially responsible contexts. This study contributes to educational research by evidencing how STEAM-oriented design-and-make activities, especially Mathematical reasoning through sensor calibration, threshold selection, and evaluation metrics, can be integrated into iterative technology development with demonstrable societal relevance. The Myosótis App serves as a model for leveraging technology to solve pressing societal challenges.

Keywords: Myosotis, Mobile Applications, Design-Based Research, Social Impact.

Resumo

O objectivo deste artigo é descrever a concepção e o desenvolvimento da Solução Myosótis, uma aplicação móvel inovadora destinada a prevenir o esquecimento acidental de crianças ou animais em veículos. O projecto foi desenvolvido no âmbito de uma dissertação de mestrado e recorreu a uma metodologia de investigação em desenvolvimento. Este artigo apresenta o processo iterativo de concepção, testagem e aperfeiçoamento da aplicação Myosótis, orientado pelos princípios da investigação em desenvolvimento. O processo iniciou-se com a identificação do problema central e a formulação da questão de investigação principal. A fase de concepção centrou-se na integração de sensores avançados (por exemplo, CO_2, humidade e detecção de presença por radar de ondas milimétricas) e de tecnologias de comunicação sem fios (LoRa e GSM), com vista ao desenvolvimento de uma aplicação responsiva e de fácil utilização com capacidade de alertas em tempo crítico. Ao longo da investigação, diversos intervenientes-chave, incluindo educadores, programadores, especialistas técnicos e utilizadores finais, participaram em várias iterações destinadas a avaliar e melhorar a usabilidade, a funcionalidade e o impacto social da aplicação. Em paralelo, o estudo analisou o projecto enquanto desenho pedagógico STEAM, promovendo a aprendizagem activa e a responsabilidade social entre os estudantes participantes através de ciclos de medição, modelação, análise de dados e tomada de decisão algorítmica. Verificou-se que a aplicação Myosótis é acessível, eficaz e socialmente relevante, respondendo com sucesso à problemática crítica da segurança em veículos e constituindo um exemplo de como a investigação baseada em design pode articular inovação tecnológica e contributo para a investigação educacional. Contudo, foram identificados desafios, nomeadamente os custos de desenvolvimento, limitações técnicas e a necessidade de optimização adicional. Este estudo incidiu sobre uma amostra limitada de participantes e contextos controlados, sendo necessários estudos futuros para avaliar a escalabilidade e a adaptabilidade da solução em contextos diversificados. Os resultados oferecem contributos relevantes para profissionais envolvidos no desenvolvimento de aplicações móveis orientadas para a resolução de problemas reais de segurança, em particular em contextos educativos e de responsabilidade social. O estudo contribui para a investigação educacional ao evidenciar como a Educação STEAM—com especial relevo para a Matemática (calibração, definição de limiares, interpretação de matrizes de confusão e taxas de erro)—pode ser integrada no desenvolvimento iterativo de soluções com impacto social. A aplicação Myosótis constitui, assim, um modelo para a utilização da tecnologia na resolução de desafios societais prementes.

Palavras-chave: Myosótis, Aplicações Móveis, Investigação Baseada em Design, Impacto Social.

Resumen

El propósito de este artículo es describir el diseño y desarrollo de la Solución Myosótis, una aplicación móvil innovadora destinada a prevenir el olvido accidental de niños o animales en vehículos. El proyecto se llevó a cabo en el marco de una tesis de máster y empleó una metodología de investigación en desarrollo. Este artículo presenta el proceso iterativo de diseño, prueba y perfeccionamiento de la aplicación Myosótis, basado en los principios de la investigación en desarrollo. El proceso comenzó con la identificación del problema central y la formulación de la pregunta de investigación principal. La fase de diseño se centró en la integración de sensores avanzados (por ejemplo, CO_2, humedad y detección de presencia mediante radar de ondas milimétricas) y tecnologías de comunicación inalámbrica (LoRa y GSM), con el fin de desarrollar una aplicación receptiva y fácil de usar con capacidad de alertas en tiempo crítico. A lo largo de la investigación, diversos actores clave, incluidos educadores, desarrolladores, expertos técnicos y usuarios finales, participaron en varias iteraciones para evaluar y mejorar la usabilidad, la funcionalidad y el impacto social de la aplicación. En paralelo, el estudio analizó el proyecto como un diseño pedagógico STEAM, favoreciendo el aprendizaje activo y la responsabilidad social entre los estudiantes participantes mediante ciclos de medición, modelización, análisis de datos y toma de decisiones algorítmica. Se constató que la aplicación Myosótis es accesible, eficaz y socialmente significativa, abordando con éxito el problema crítico de la seguridad en vehículos y proporcionando un ejemplo empírico de cómo la investigación basada en el diseño puede articular innovación tecnológica y contribución a la investigación educativa. No obstante, se identificaron desafíos como los costes de desarrollo, las limitaciones técnicas y la necesidad de una mayor optimización. Este estudio se centró en una muestra limitada de participantes y en entornos controlados, por lo que se requieren investigaciones futuras para evaluar la escalabilidad y la adaptabilidad en contextos diversos. Los resultados ofrecen aportaciones valiosas para los profesionales que desarrollan aplicaciones móviles orientadas a abordar problemas reales de seguridad, especialmente en contextos educativos y de responsabilidad social. Este estudio contribuye a la investigación educativa al mostrar cómo la Educación STEAM—con énfasis en la Matemática (calibración, selección de umbrales, interpretación de matrices de confusión y tasas de error)—puede integrarse en el desarrollo iterativo de soluciones con impacto social. La aplicación Myosótis se presenta, así, como un modelo para aprovechar la tecnología en la resolución de desafíos sociales urgentes.

Palabras clave: Myosótis, Aplicaciones Móviles, Investigación Basada en el Diseño, Impacto Social.

1 INTRODUCTION

Mobile technology and device internet connectivity (IoT, Internet Of Things) have become an indispensable part of modern life, deeply integrated into our daily routines and activities. Rapid innovation has enabled novel forms of sensing, communication, and user interaction, creating opportunities for both learning and public safety. In the context of education, mobile technologies hold immense potential to address individual learning needs and foster innovation, particularly when students engage in authentic problem solving that connects disciplinary knowledge to societal challenges. However, the translation of such educational innovation into safety-oriented applications remains under-explored in the literature, especially when school-based STEAM projects are positioned as sites of design-based research.

In the 21st century, the increasing global demand for education, rapid developments in Information and Communication Technologies (ICT), and the evolving expectations of learners have compelled educational institutions to adapt. While higher education has embraced these changes to some extent, there remains a lack of widespread integration of mobile technologies into teaching and learning strategies (Traxler & Kukulska-Hulme, 2007). More recent studies, such as Krull and Duart (2017), indicate a growing interest in mobile learning research, focusing particularly on the development of mobile applications and their adoption by students and educators. However, there is still a scarcity of studies on methodological frameworks for designing sustainable and impactful mobile learning solutions (Nouri et al., 2016).

This study addresses a dual gap: (i) a persistent and critical safety problem—accidental entrapment of children and animals in vehicles—and (ii) an educational research need to document how STEAM learning can be operationalised through design-based research (DBR) that yields both a functional artefact and transferable design knowledge. Incidents of paediatric vehicular heatstroke and animal heatstroke tragically occur with alarming frequency worldwide. In Portugal, for instance, at least one child dies annually from being left inside a vehicle, with similar patterns observed in other countries such as the United States, where the numbers are considerably higher. These realities motivate interventions that combine technological reliability with education for social responsibility. To tackle this challenge, this paper reports on the design and development of the Myosótis solution, a mobile application integrated with a custom-designed device and embedded software developed as part of a master's degree project using a design-based research methodology. The solution aims to detect and alert users to the presence of children or animals in locked vehicles, leveraging advanced sensor technologies (e.g., CO_2, humidity, and mmWave presence detection) and wireless communication systems. Importantly, the development process was enacted within a school robotics club (ages 10–15), positioning students as legitimate co-designers and enabling the study to examine learning outcomes alongside technological performance.

The structure of this paper begins with an overview of the mobile solution and the significance of design-based research in technological innovation. It then describes the context and objectives of the project, followed by an explanation of the methodology employed. The findings and analysis are presented, highlighting the app's functionality, user experience, and social impact. Finally, the paper concludes with a discussion of the broader implications for education and technology integration in addressing pressing societal challenges, with explicit attention to the Mathematical and STEAM practices mobilised during development and evaluation.

From an educational perspective, safety applications also provide authentic contexts for quantitative reasoning (risk estimation, threshold definition, error trade-offs) and data literacy (interpreting sensor streams), thereby linking public health concerns to STEAM pedagogies.

2 THEORETICAL FRAMEWORK

2.1 Child Safety and Mobile Applications

Pediatric Vehicular Heatstroke (PVH) has emerged as one of the leading causes of non-traffic-related child fatalities in the United States, with over 900 children losing their lives since 1998 due to being left or trapped in vehicles (Williams & Grundstein, 2017). Socio-economic and environmental factors play a significant role in these incidents, as high ambient temperatures and financial constraints can prevent families from running air conditioning to conserve fuel (Ngeni et al., 2024). Research highlights that over half of these tragedies occur when caregivers unintentionally forget a child in a vehicle, a scenario exacerbated by the belief among many parents that such an oversight could not happen to them (Williams & Grundstein, 2017).

Interestingly, while median income alone does not correlate significantly with PVH cases, states with a higher median income ratio to fatalities, such as North Dakota and Maine, report fewer deaths, suggesting economic resilience as a mitigating factor (Ngeni et al., 2024). Furthermore, the effectiveness of policies designed to combat PVH-related deaths varies, with some regions, such as Texas and Florida, experiencing persistently high rates even after implementing preventative measures (Ngeni et al., 2024). Alongside policy interventions, technological solutions, including Arduino-based safety alert systems that monitor CO_2, temperature, and motion, offer promising avenues for prevention by sending alerts to caregivers and authorities during critical situations (Hazizan et al., 2020; Visconti et al., 2020).

Studies indicate that women exhibit a more positive attitude and stronger intention to adopt these technologies compared to men, underscoring the need for inclusive design and marketing strategies to maximise adoption (Albert & Kerbis, 2019). The risks are not confined to children: animals left in vehicles are also highly susceptible to heatstroke, and neglect in such contexts can have secondary effects on children, particularly in cases of animal hoarding (Crawford, 2020). Addressing PVH requires a multifaceted approach that combines public health messaging, advanced technological interventions, and nuanced policy frameworks to effectively reduce these preventable tragedies (Williams & Grundstein, 2017; Ngeni et al., 2024).

2.2 STEAM Approach in Mobile Application Development

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach represents an innovative interdisciplinary framework that merges technical expertise with artistic creativity to foster holistic learning. By integrating these diverse disciplines, STEAM equips learners with the skills needed to address complex societal challenges, bridging analytical thinking with creative problem-solving (Fuller et al., 2021). This approach is increasingly recognised for its transformative potential in educational contexts, particularly in mobile application development, where it encourages the design of functional, user-friendly, and aesthetically engaging solutions.

The STEAM approach has been effectively applied in the development of mobile applications, as demonstrated by several studies (Sekhar et al., 2012; Zhi, 2016). These studies highlight the integration of STEAM principles into learning models that enhance students' cognitive, psychomotor, and affective skills. For instance, Sekhar et al. (2012) utilised STEAM principles to develop an Android-based physics learning application, incorporating traditional musical instruments and project-based learning. This innovative approach not only engaged students in scientific concepts but also bridged cultural and technological elements, fostering a deeper understanding of both science and the arts. A systematic literature review conducted by Maghfiroh et al. (2023) analysed 30 indexed articles, revealing the widespread adoption of STEAM in science learning innovations, including applications integrating traditional musical instruments and strategies aligned with the Next Generation Science Standards (NGSS). The findings underscored the effectiveness of STEAM-based learning activities in improving critical thinking, collaboration, leadership, and other essential skills, particularly in elementary education settings (Roshayati et al., 2023).

Mobile applications developed using the STEAM approach emphasise the integration of its core disciplines to create solutions that are both practical and innovative:

- Science: Applications incorporate principles such as those underpinning sensor technologies (e.g., temperature and CO_2 monitoring), which are critical for safety-focused tools like child protection systems (Fuller et al., 2021).
- Technology: Programming, data analytics, and Internet of Things (IoT) systems are leveraged to ensure responsive and adaptive functionality (Maghfiroh et al., 2023).
- Engineering: The use of iterative design and problem-solving methodologies ensures the feasibility and efficiency of complex systems (Zhi, 2016).
- Arts: User experience is enhanced through visually appealing interfaces, which promote engagement and accessibility (Sekhar et al., 2012).

- Mathematics: In safety-critical systems, Mathematics is not ancillary; it structures the core decisions of detection and alerting. In this study, Mathematical practices included sensor calibration (measurement and scaling), threshold selection (trade-offs between false positives and false negatives), and performance evaluation using confusion matrices, normalised rates, and error analysis. These practices align STEAM enactment with the editorial profile of PRATICA, foregrounding quantification, modelling, and evidence-based decision-making as integral to learning and design.

These principles have been successfully demonstrated in studies such as Zhi's (2016) work on a project-based blended learning model for mobile application development. Extending this line of work, the present study treats the Myosótis project as a STEAM learning design in which Mathematical reasoning supports reliable sensing and ethically responsible decision-making in a real-world context.

The STEAM approach not only fosters innovation in mobile application development but also promotes equity and diversity in education by providing inclusive opportunities for students from varied backgrounds (Roshayati et al., 2023). This inclusivity is essential in cultivating responsible global citizens capable of addressing societal challenges through technological innovation. By engaging students in interdisciplinary projects, such as child safety monitoring systems or environmentally conscious applications, STEAM education instils a sense of social responsibility alongside technical competence. Furthermore, integrating traditional elements, such as musical instruments, with modern technology exemplifies the cultural adaptability of STEAM methodologies (Sekhar et al., 2012; Maghfiroh et al., 2023). These practices not only preserve cultural heritage but also enrich the learning experience by contextualising scientific and technological concepts within familiar frameworks.

3 THE METHOD

This study adopts a development research methodology to design, develop, and evaluate a mobile application aimed at preventing children from being forgotten in vehicles. The solution was developed within a school Robotics Club (basic education, 2nd and 3rd cycles; ages 10–15), positioning the educational setting as the primary site of design, iteration, and learning. The development research methodology was selected due to its iterative approach, which integrates practical application, theoretical reflection, and systematic evaluation in real-world educational contexts (Van den Akker, 1999). Consistent with DBR, the study aimed to produce both a functional artefact (the Myosótis solution) and design principles relevant to STEAM-oriented educational innovation.

3.1 Development Research Framework

The study aligns with Van den Akker's (1999) framework for development research, comprising the following four phases:

Preliminary Investigation: The preliminary investigation involved collecting data to understand the causes and consequences of incidents where children are forgotten in vehicles. In educational terms, this phase also functioned as a problem-framing activity in which students engaged with evidence, media reports, and stakeholder perspectives to define requirements and ethical constraints.

Theoretical Embedding: An iterative development process enabled continuous refinement based on stakeholder feedback and real-world testing. The approach involved integrating sensors (CO_2, temperature/humidity, mmWave presence) with notification systems to alert caregivers promptly. Mathematical modelling guided the selection of thresholds and decision rules under uncertainty.

Empirical Testing: The solution was evaluated for practicability and effectiveness in real-world contexts with the target audience. Performance was quantified using error rates and confusion matrices, supporting transparent claims about reliability. Documentation, Analysis, and Reflection: Systematic documentation and analysis of design decisions, implementation constraints, and outcomes were conducted to refine the solution and provide guidance for future development and research projects. Reflection explicitly addressed how STEAM practices—especially Mathematical reasoning—were enacted during iteration.

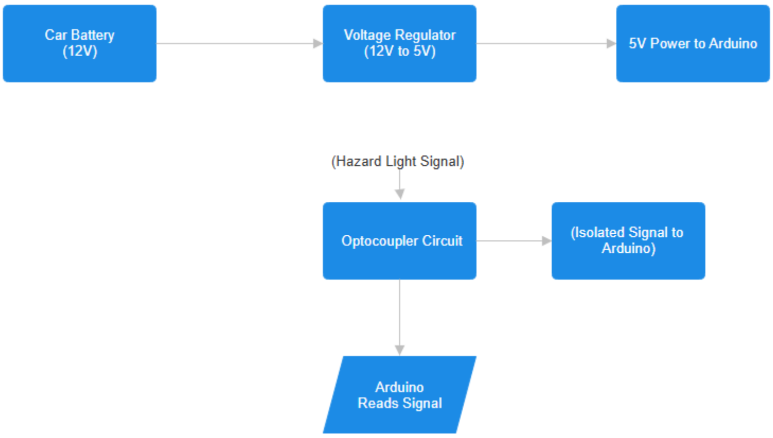
3.2 Development Process

The study will employ an iterative process for the development of mobile application for child safety. The preliminary investigation will focus on collecting data to understand the causes and consequences of incidents where children are forgotten in vehicles. This phase will also include a comprehensive review of existing safety technologies to identify current solutions and gaps, ensuring the proposed application effectively addresses the identified challenges.

Figure 1 illustrates the initial technical framework employed to support the iterative development process of the proposed mobile application. The system harnesses power directly from the vehicle's 12V battery, converting it through a voltage regulator to supply a stable 5V output essential for the Arduino microcontroller's functionality. This microcontroller acts as the core computing unit, responsible for processing incoming signals. Additionally, to safely detect and interpret vehicle-specific signals—such as hazard lights—the system integrates an optocoupler circuit. This optocoupler provides electrical isolation, ensuring the Arduino receives a secure, isolated input signal without interference or potential damage from voltage fluctuations. This technical arrangement underpins the reliability of the safety solution, directly addressing gaps identified during the preliminary investigation phase regarding existing child-safety technologies.

Figure 1

Interface diagram block

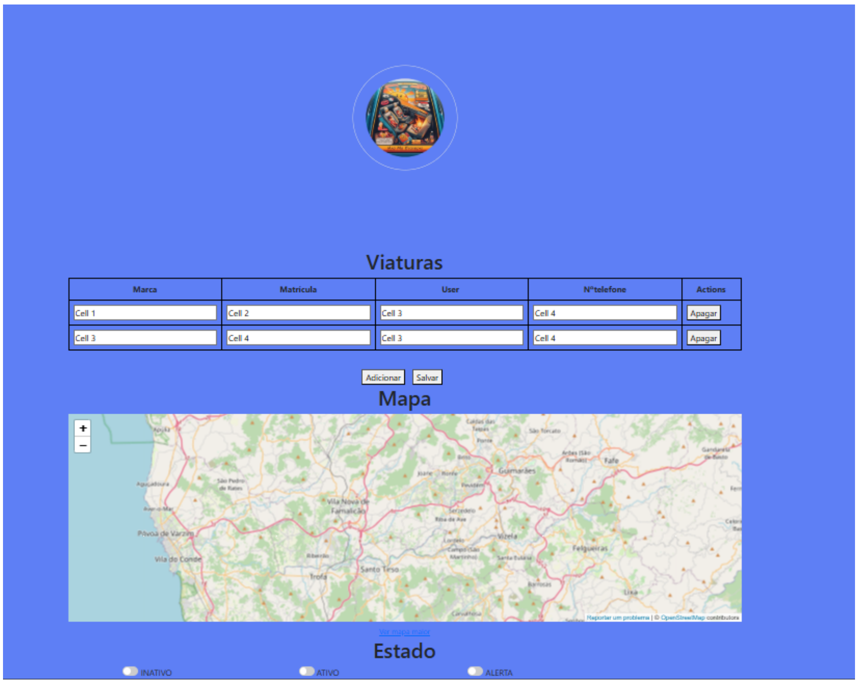


The development iterations will involve an iterative process to ensure continuous refinement of the solutions based on stakeholder feedback and real-world testing. For the child safety application, this process will include the integration of sensors to detect millimetric wavelength radar sensor, temperature, and motion, combined with notification systems designed to promptly alert caregivers, enhancing both functionality and user experience.

Figure 2 presents the initial user control interface designed for the Myosótis mobile application. This interface provides users with essential information management related to vehicle monitoring, clearly structured in a straightforward and intuitive layout. It includes a section titled 'Viaturas', with vehicle details. Action buttons allow for quick management of these details. The map ('Mapa') provides real-time geographical tracking capabilities, enhancing the application's practicality and ease of use. Aditionally, users have the ability to toggle vehicle states (active/inactive), ensuring continuous monitoring and management efficiency. This early version reflects user-centric design principles applied throughout the iterative development process, setting a foundation for future usability improvements and feature enhancements.

Figure 2

First version of the application control interface



The evaluation phase will utilize two methods to assess usability: heuristic evaluation and user testing. Heuristic evaluation will be conducted during the design stage by experts to identify usability issues and ensure the application meets established usability principles. User testing will involve a sample of users resembling the target audience, focusing on assessing the application's functionality, user experience, and overall effectiveness in addressing its intended purpose.

The data collection methods will include a combination of qualitative and quantitative approaches. Interviews with experts will provide valuable insights to enhance the design and functionality of the applications. Field notes will document observations, challenges encountered, and solutions implemented throughout the development process, offering a detailed contextual record. Additionally, questionnaires will be used to gather students' perceptions regarding the usability, effectiveness, and acceptance of the applications, ensuring feedback from the target audience is incorporated into the iterative development process. We use the designation Si for student i to code the students' responses, with i = 1,...5. Quantitative performance evidence (e.g., confusion matrices) was treated as both an engineering validation practice and an educational outcome related to Mathematical literacy and evidence-based reasoning.

4 RESULTS

The development and evaluation of the Myosótis Solution followed an iterative, design-based research approach, integrating multiple testing phases with expert and user feedback to enhance its usability, effectiveness, and social impact. This section presents the key findings from the usability evaluations, sensor performance tests, and real-world trials, highlighting the system's reliability, accessibility, and effectiveness in preventing child and animal entrapment in vehicles. In addition, the section reports how performance evaluation practices supported students' Mathematical reasoning about error, trade-offs, and decision thresholds.

A comparative analysis was conducted between CO_2 sensors and millimetre-wave radar sensors to examine true and false positive detection rates obtained during experimental testing. Detection outcomes were analysed using normalised performance metrics, ensuring that each detection class summed to 100%. The results indicate that CO_2-

based detection is highly susceptible to environmental fluctuations, resulting in a considerable number of false positives, particularly in ventilated or partially open vehicle conditions. In contrast, millimetre-wave radar sensors demonstrated substantially higher detection accuracy, reliably identifying the presence of children or animals even in stationary conditions. These findings informed a design decision grounded in quantitative evidence, illustrating how confusion-matrix reasoning can guide safety-critical development and constitute an explicit Mathematics-in-STEAM learning outcome.

During practical trials, the system enabled continuous real-time monitoring of environmental and presence-related variables, including CO_2 concentration, humidity levels, and occupancy status. This monitoring capability provided immediate feedback to users and allowed the system to promptly identify potentially hazardous situations, triggering alerts when predefined thresholds were exceeded. Such functionality reinforced both the reliability of the solution and its pedagogical value, as students engaged in analysing threshold behaviour, system responsiveness, and the implications of false positives and false negatives in real-world safety scenarios.

4.1 Iterative Testing and Refinement

The Myosótis system underwent multiple iterations, beginning with concept validation and progressing through prototype development, usability assessments, and real-world trials. Each phase contributed to refining the hardware and software components, ensuring a seamless integration of sensor technologies and communication systems.

Early Prototype Evaluations: Initial testing of CO_2 sensors revealed significant limitations, including false positives due to environmental CO_2 fluctuations and ventilation systems. This led to a shift towards millimetre-wave radar sensors, which demonstrated superior accuracy in detecting human and animal presence inside vehicles, even when the occupant was stationary or asleep.

Usability Testing with Experts: A group of multidisciplinary specialists (including experts in multimedia, mathematics, and technology education) conducted heuristic evaluations based on usability principles outlined by Nielsen and Molich (1990). The findings emphasised the importance of automation, minimal user intervention, and an intuitive interface to ensure the system's reliability under real-world conditions. Expert feedback also recommended making quantitative performance indicators (e.g., signal strength, detection confidence) interpretable to non-expert users without increasing cognitive load.

Sensor Performance Validation: The transition to millimetre-wave radar sensors significantly improved detection accuracy. The sensors effectively distinguished between living beings and inanimate objects, reducing false positives and ensuring a high detection success rate across different vehicle types and seating arrangements.

4.2 System Reliability and Technological Integration

Despite its high accuracy and robust functionality, the development and evaluation phases revealed certain challenges and limitations that required careful consideration. The Myosótis solution was designed to operate independently of user input, thereby minimising the risk of human error while ensuring seamless integration with existing vehicle systems. A key aspect of its functionality was real-time detection and alerts, where the system automatically identified the presence of a child or animal in a parked vehicle and triggered instant notifications. These alerts were reliably delivered via GSM-based SMS notifications and push alerts through the mobile application, ensuring swift action when necessary.

Crucially, the system incorporated an advanced emergency response mechanism. In real-world conditions, if the primary user failed to acknowledge an alert within a specified timeframe, the system automatically escalated the notification to pre-registered emergency contacts. This ensured a rapid response in critical situations and reinforced the overall reliability of the Myosótis Solution. Such refinements, developed through iterative testing, significantly enhanced both the usability and dependability of the application, contributing to an efficient and user-friendly safety solution. From an educational standpoint, this escalation logic provided a concrete example of algorithmic decision-making under time constraints, enabling discussion of ethical design, risk, and accountability.

To address potential network coverage issues in underground parking areas or remote locations, the system incorporated LoRaWAN technology as a backup communication channel, ensuring reliable alert transmission even in low-connectivity environments. Furthermore, universal vehicle compatibility was a fundamental design principle, achieved by enabling the system to function across all vehicle makes and models without complex modifications. A key component of this was the Arduino microcontroller's ability to interpret specific vehicle signals, notably the parking brake indicator light. This light was identified as a consistent and non-intrusive trigger mechanism. To ensure safe electrical isolation and prevent interference, the Arduino received the signal from the parking brake light via an optocoupler circuit. This intelligent detection mechanism ensured that the primary radar presence sensor was only activated when the vehicle was stationary and parked, thereby optimizing both energy efficiency and system usability. Students engaged in measurement and estimation tasks to evaluate power consumption, reinforcing Mathematical reasoning about rates, constraints, and system optimisation.

4.3 Usability and User Experience

Despite its high accuracy and robust functionality, the development and evaluation phases revealed certain challenges and limitations, particularly concerning usability and user engagement. Extensive testing was conducted with a diverse group of end-users, including parents, pet owners, and educators, to ensure optimal accessibility and intuitive interaction. The results indicated that the mobile application interface, figure 6, was highly intuitive, requiring minimal configuration, with users successfully navigating the app, managing emergency contacts, and responding to alerts without additional guidance. However, feedback highlighted that SMS alerts were sometimes missed when phones were on silent mode, leading to the implementation of a vibration feature to enhance the visibility of urgent notifications. This adjustment exemplifies user-centred refinement based on empirically observed breakdowns in real use.

4.4 Educational Impact and Student Engagement

The students actively participated in every stage of the project, from ideation to construction, hardware design, software development, app interface creation, and testing. This comprehensive involvement provided them with a holistic understanding of the engineering process and the importance of each step in developing a technological solution. As a STEAM learning design, the project operationalised: (i) Science through sensing principles; (ii) Technology through programming and networking; (iii) Engineering through iterative prototyping; (iv) Arts through user-centred interface design; and (v) Mathematics through calibration, threshold selection, performance evaluation, and error analysis.

Through participation, students gained insights into how technology can address real-world problems and create positive social impact. They developed a clear perception of the relevance of their work by witnessing the potential benefits of their solutions for society. Moreover, the process fostered responsibility and social awareness. Importantly, Mathematical reasoning functioned as a bridge between "making" and "evidence": students used quantitative indicators to justify design choices rather than relying on intuition alone.

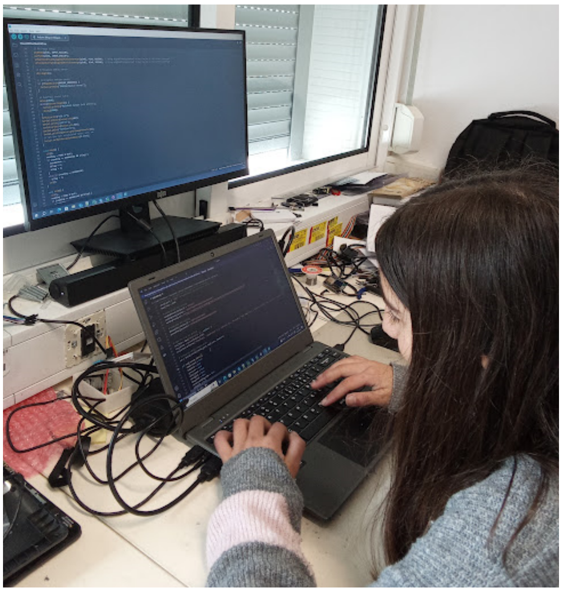
To illustrate the impact of participation, testimonies were collected from students, highlighting how the project influenced their perspectives. Many students expressed a heightened appreciation for the importance of their work and a commitment to continue developing technologies that address social issues. Additionally, engagement metrics showed high levels of participation and dedication, demonstrating investment in the project's success. These outcomes align with STEAM aims of integrating disciplinary knowledge with civic-oriented innovation.

The integration of the STEAM methodology (Science, Technology, Engineering, Arts, and Mathematics) in the development of the Myosótis application had a significant impact on the students involved in the project. The STEAM approach promoted active learning and social responsibility, providing students with a holistic understanding of the engineering process and the importance of each step in developing a technological solution. Students actively participated in all phases of the project, from ideation to construction, hardware design, software development, application interface creation, and testing. This comprehensive participation allowed them to gain a deep understanding of how technology can solve real-world problems and create a positive social impact. They developed a clear perception of the relevance of their work by witnessing firsthand the potential benefits of their solutions for society.

Moreover, the process fostered a sense of responsibility and social awareness among the students. By engaging in projects with tangible social implications, they realized the importance of creating technologies that serve the greater good. This experience not only enhanced their technical skills but also cultivated a deeper understanding of their role as socially responsible innovators. To illustrate the impact of their participation, testimonials were collected from the students, highlighting how the project influenced their perspectives. Many students expressed a newfound appreciation for the importance of their work and a commitment to continue developing technologies that address social issues. Additionally, engagement metrics showed high levels of participation and dedication, further demonstrating the students' investment in the project's success.

Figure 3

Student programing



The image above shows a student using the Visual Studio Code IDE to write code for the user application. The student is working with a two-monitor setup, which is more practical for this environment. The equipment scattered around, including soldering materials and a microcontroller, were part of the development process. The microcontroller used is an Arduino Uno, which is connected to various sensors and modules to test the functionality of the application. The soldering materials were used to create custom circuits and connections for the sensors, ensuring reliable data transmission and integration with the Arduino-based environment

4.5 Challenges and Areas for Further Development

Despite the Myosótis Solution's high accuracy and robust functionality, several challenges and limitations emerged during its development and evaluation. One of the primary concerns was development costs, as the integration of advanced radar sensors and secure communication modules (GSM and LoRaWAN) resulted in higher-than-anticipated production expenses. To ensure wider adoption, future iterations should focus on cost-reduction strategies without compromising system reliability. Another key challenge was battery efficiency, as the device operates on a standalone rechargeable battery. While this ensures independence from the vehicle's power system, optimising power consumption for extended operation remains a priority for further refinement.

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Additionally, the scalability and broader implementation of the system require further investigation. The study was conducted within controlled environments, and real-world trials in diverse climatic and vehicular conditions are essential to evaluate its adaptability across different markets and user demographics. Expanding field testing will provide valuable insights into the system's long-term reliability and performance, ensuring it remains an effective and accessible solution for a wide range of users.

4.6 The testimonials of the five students who developed the project:

4.6.1. Personal Growth and Skill Development

This dimension highlights how the project contributed to students' individual learning, skill acquisition, and career aspirations.

- Student 1: "Participating in the Myosótis project has been a transformative experience for me. I never realized how much impact technology could have on solving real-world problems until I saw our app in action. It has inspired me to pursue a career in technology."
- Student 2: "Working on the Myosótis application allowed me to see the direct connection between what we learn in the classroom and its application in real life. It was incredibly rewarding to know that our work could potentially save lives."
- Student 3: "The project taught me the importance of collaboration and interdisciplinary learning. Combining our knowledge in science, technology, engineering, arts, and mathematics made our solution more robust and innovative. I now understand the value of a STEAM approach in tackling complex issues."
- Student 5: "The hands-on experience we gained through this project was invaluable. It not only enhanced my technical skills but also helped me develop a deeper understanding of my role as a socially responsible innovator."

4.6.2. Social Impact Awareness and Responsibility

This dimension illustrates how the project fostered a deeper understanding of technology's societal role and cultivated a sense of civic responsibility in the students.

- Student 1: "...[I never realized how much impact technology could have on] solving real-world problems until I saw our app in action. It has inspired me to pursue a career in technology with a focus on social good."
- Student 2: "...It was incredibly rewarding to know that our work could potentially save lives."
- Student 3: "...I now understand the value of a STEAM approach in tackling complex issues."
- Student 4: "Being part of this project has given me a sense of responsibility and purpose. I am more aware of the societal impact of technology and am committed to developing solutions that benefit the community."
- Student 5: "...[The project] also helped me develop a deeper understanding of my role as a socially responsible innovator."

5 DISCUSSION AND CONCLUSION

The Myosótis application represents a substantive advance in mobile technology for social impact, offering an innovative approach to preventing child and animal fatalities in parked vehicles. Developed through a development research methodology, the study demonstrates how iterative testing, user feedback, and technological refinement can yield a solution that is both effective and usable. The integration of millimetre-wave radar sensing, real-time alerts, and LoRaWAN back-up communication proved reliable in real-world conditions, positioning Myosótis as a meaningful contribution to safety-oriented mobile applications.

This work aligns with research on paediatric vehicular heatstroke (PVH), a leading cause of non-traffic-related child deaths (Williams & Grundstein, 2017). By enabling autonomous detection of children and animals, Myosótis directly targets caregiver forgetfulness, identified as a major causal mechanism (Ngeni et al., 2024). Sensor-based alert systems have been recognised as an important mitigation strategy (Hazizan et al., 2020; Visconti et al., 2020).

Evidence that women may show higher adoption intentions than men further reinforces the need for inclusive design and communication strategies to maximise uptake (Albert & Kerbis, 2019).

5.1 Development-Based Research and User-Centred Design

Myosótis was designed using development research, incorporating stakeholder feedback across cycles to refine usability and performance. Consistent with mobile application design literature, early and repeated usability assessments supported timely identification of interface and workflow issues (Sekhar et al., 2012; Zhi, 2016). Three elements were particularly influential:

User-centred design: Iterations were driven by the needs of car owners, parents, and pet owners, prioritising low configuration burden and rapid comprehension under stress.

Technological innovation: mmWave radar enabled reliable detection of stationary occupants, addressing limitations observed with motion-based or CO_2 sensing; LoRaWAN increased robustness in low-connectivity settings.

Interdisciplinary collaboration: Contributions from engineering, mobile development, and user experience expertise strengthened technical reliability and interaction quality, illustrating the value of STEAM-oriented collaboration (Fuller et al., 2021; Maghfiroh et al., 2023).

The project also illustrates STEAM education as a vehicle for civic-oriented innovation. Students' reflections indicate that participation strengthened their understanding of how classroom knowledge can be mobilised for social good (S1–S5), while fostering collaboration and responsibility.

Contribution to educational research: Beyond producing an artefact, the study contributes design knowledge on how DBR can structure STEAM learning around socially consequential problems. Mathematics operated as a key integrator: students used calibration data to justify sensor choices, applied quantitative thresholds to manage safety trade-offs, and interpreted confusion matrices to substantiate performance claims. This provides a practice-informed, evidence-based account consistent with PRATICA's educational remit.

Future research should examine scalability (infrastructure and load management), cultural and regulatory adaptation, and advanced integrations (e.g., AI-assisted detection and predictive risk modelling). Sustainability and power efficiency also remain priorities for long-term deployment.

5.2 Social Impact and Public Awareness

Myosótis extends beyond individual use by supporting public safety awareness and, potentially, policy conversations. Its primary social value lies in reducing preventable harm through automated monitoring and timely alerts to drivers and emergency contacts, without relying on manual reminders (Williams & Grundstein, 2017). Given that awareness campaigns alone are insufficient (Ngeni et al., 2024), the solution contributes to a broader prevention ecology by combining technology with education, including informational resources that promote safer practices. Positioning the development in a school context further demonstrates how STEAM projects can cultivate responsibility while producing tangible safety innovations. The emergency-contact feature also enables community-based support and rapid escalation when the primary user does not respond.

5.3 Challenges and Research Gaps

Several challenges warrant further investigation. First, long-term adoption and retention remain uncertain; longitudinal fieldwork is needed to understand sustained use, particularly when critical incidents are rare (Williams & Grundstein, 2017). Second, evaluation methods could be strengthened by combining expert review and user testing with automated measures (e.g., interaction logs), and—where appropriate—instrumented observation tools. Third, privacy and security require continuing attention. Although designed to be GDPR-compliant, additional work on privacy-preserving approaches and robust encryption may increase trust and reduce adoption barriers (Albert & Kerbis, 2019).

Overall, Myosótis illustrates how development research can produce socially responsible mobile safety applications while generating transferable educational insights. Through iterative design, rigorous usability work, and interdisciplinary collaboration, the study offers a credible pathway for aligning technological innovation with educational outreach and measurable social benefit.

CONCLUSION

This study reported the design and development of the Myosótis Solution—an IoT-enabled mobile safety application—using a design-based (development) research methodology. The main technological contribution is a reliable detection-and-alert architecture grounded in iterative testing and quantified performance evidence, with mmWave radar outperforming CO_2-based approaches under realistic conditions. The principal educational contribution is an empirically documented STEAM learning design in which Mathematics (calibration, thresholding, and confusion-matrix reasoning) played a central role in evidence-based decision-making. Practically, the findings inform developers and educators seeking to design socially responsible mobile applications that integrate user-centred refinement with authentic, data-driven STEAM learning. Future research should extend field trials across diverse contexts and examine long-term adoption, scalability, and privacy-preserving implementations.

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